PERSPECTIVES ON THE NEAR-EARTH OBJECT (NEO) THREAT

SIMON P. WORDEN, BRIGADIER GENERAL, USAF
Deputy Director for Operations
United States Space Command
Peterson AFB, CO

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The opinions and concepts expressed are those of the author and do not necessarily represent the position of the Department of Defense or the United States Space Command

INTRODUCTION

Interest in the threat caused by natural objects ("Near-Earth Objects" or NEOs) impacting the earth or its atmosphere is growing. High-level commissions have met to consider the problem in such places as the United Kingdom. In the United States, NASA has devoted a few million dollars per year to studying the phenomenon. But no concrete plan exists to address the overall NEO problem.

The U.S. Department of Defense (DoD) has not perceived the NEO issue as pressing. However, DoD is assisting NASA in studying the problem. It has been DoD-developed technology, particularly in the space surveillance area, which has obtained the bulk of data we currently have on NEOs.

I have been asked to address my perspectives on the NEO threat and what should be done about it. I make the following comments not as a representative of the U.S. DoD, but rather as a scientist who has studied NEOs, and as a space expert familiar with the technologies that might be applicable to the problem.

THE THREAT

Two and a half months ago, Pakistan and India were at full alert and poised for a large-scale war, which both sides appeared ready to escalate into nuclear war. The situation has defused–for now. Most of the world knew about this situation and watched and worried. But few know of an event over the Mediterranean on June 6th of this year that could have had a serious bearing on that outcome. U.S. early warning satellites detected a flash that indicated an energy release comparable to the Hiroshima burst. We see about 30 such bursts per year, but this one was one of the largest we have ever seen. The event was caused by the impact of a small asteroid, probably about 5-10 meters in diameter, on the earth's atmosphere. Had you been situated on a vessel directly underneath, the intensely bright flash would have been followed by a shock wave that would have rattled the entire ship, and possibly caused minor damage.

The event of this June received little or no notice as far as we can tell. However, if it had occurred at the same latitude just a few hours earlier, the result on human affairs might have been much worse. Imagine that the bright flash accompanied by a damaging shock wave had occurred over India or Pakistan. To our knowledge, neither of those nations have the sophisticated sensors that can determine the difference between a natural NEO impact and a nuclear detonation. The resulting panic in the nuclear-armed and hair-triggered opposing forces could have been the spark that ignited a nuclear horror we have avoided for over a half century.

I've just relayed one aspect of NEOs that should worry us all. As more and more nations acquire nuclear weapons–nations without the sophisticated controls and capabilities built up by the United States over the 40 years of Cold War–we should ensure the 30-odd yearly impacts on the upper atmosphere are well understood by all to be just what they are.

A few years ago those of us charged with protecting this Nation's vital space systems, such as the Global Positioning System, became aware of another aspect of the NEO problem. This was the Leonid meteor storm. This particular storm occurs every 33 years. It is caused by the debris from a different type of NEO–a comet. When the earth passes through the path of a comet, it can encounter the dust thrown off by that comet through its progressive passes by the sun. This dust is visible on the earth as a spectacular meteor storm. But our satellites in space can experience the storm as a series of intensely damaging micrometeorite strikes. We know about many of these storms and we have figured out their parent comet sources. But there are some storms arising from comets that are too dim for us to see that can produce "surprise" events. One of these meteor storms has the potential of knocking out some or even most of our earth-orbiting systems. If just one random satellite failure in a pager communications satellite a few years ago seriously disrupted our lives, imagine what losing dozens of satellites could do.

Most people know of the Tunguska NEO strike in Siberia in 1908. An object probably less than 100 meters in diameter struck Siberia, releasing equivalent energy of up to 10 megatons. Many experts believe there were two other smaller events later in the century—one in Central Asia in the 1940s and one in the Amazon in the 1930s. In 1996, our satellite sensors detected a burst over Greenland of approximately 100 kiloton yield. Had any of these struck over a populated area, thousands and perhaps hundreds of thousands might have perished. Experts now tell us that an even worse catastrophe than a land impact of a Tunguska-size event would be an ocean impact near a heavily populated shore. The resulting tidal wave could inundate shorelines for hundreds of miles and potentially kill millions. There are hundreds of thousands of objects the size of the Tunguska NEO that come near the earth. We know the orbits of just a few.

Finally, just about everyone knows of the "dinosaur killer" asteroids. These are objects, a few kilometers across, that strike on time scales of tens of millions of years. While the prospect of such strikes grabs people's attention and make great catastrophe movies, too much focus on these events has, in my opinion, been counterproductive. Most leaders in the United States or elsewhere believe there are more pressing problems than something that may only happen every 50-100 million years. I advocate we focus our energies on the smaller, more immediate threats. This is not to say we do not worry about the large threats. However, I'm reasonably confidant we will find almost all large objects within a decade or less. If we find any that seem to be on a near-term collision course–which I believe unlikely–we can deal with the problem then.

WHAT SHOULD WE DO?

First and foremost, when an object strikes the earth, we must know exactly what it is and where it hit. Fortunately, our early warning satellites already do a good job of this task. Our next generation system, the Space-Based Infrared System, will be even better. The primary difficulty is that this data is also used for vital early warning purposes and its detailed performance is classified. However, in recent years, the U.S. DoD has been working to provide extracts of this data to nations potentially under missile attack with cooperative programs known as "Shared Early Warning." Some data about asteroid strikes have also been released to the scientific community. Unfortunately, it takes several weeks for this data to be released. I believe we should work to assess and release this data as soon as possible to all interested parties, while ensuring sensitive performance data is safeguarded.

We have studied what a NEO warning center might look like. I believe adding a modest number of people, probably less than 10, to current early warning centers and supporting staffs within Cheyenne Mountain could form the basis of a Natural Impact Warning Clearinghouse.

Perhaps the most urgent mid-term task has already begun. This is the systematic observation and cataloging of nearly all potentially threatening NEOs. We are probably about halfway through cataloging "large" NEOs (greater than a kilometer in diameter). It is interesting to note the most effective sensor has been the MIT Lincoln Lab LINEAR facility in New Mexico, which is a test bed for the next generation of military ground-based space surveillance sensors. But this ground-based system, however effective, can only address the "large," highly unlikely threats. We find out every few weeks about "modest" asteroids a few hundred meters in diameter. Most sail by the earth unnoticed until they have passed. In recent months, the object 2002MN had just this sort of near miss–passing only a few tens of thousands of kilometers from the earth. Ground-based systems such as LINEAR are unable to detect one of the most potentially damaging classes of objects, such as comets that come at us from the direction of the sun. New space-surveillance systems capable of scanning the entire sky every few days are what is needed.

New technologies for space-based and ground-based surveys of the entire space near the earth are available. These technologies could enable us to completely catalog and warn of objects as small as the Tunguska meteor (less than 100 meters in diameter). The LINEAR system is limited primarily by the size of its main optics–about one meter in diameter. By building a set of three-meter diameter telescopes equipped with new large-format Charged Coupled Devices, the entire sky could be scanned every few weeks and the follow-up observations necessary to accurately define orbits, particularly for small objects, could be done.

The most promising systems for wide-area survey–particularly to observe close to the sun to see objects coming up from that direction–are space-based surveillance systems. Today the only space-based space surveillance system is the DoD's Midcourse Space Experiment (MSX) satellite. This was a late 1990s missile defense test satellite, and most of its sensors have now failed. However one small package weighing about 20 kg and called the Space-Based Visible sensor is able to search and track satellites in geosynchronous orbit (GEO) using visible light. This has been a phenomenally successful mission, having lowered the number of "lost" objects in GEO orbit by over a factor of two. MSX is not used for imaging asteroids, but a similar sensor could be. The Canadian Space Agency, in concert with the Canadian Department of National Defense, is considering a "microsatellite" experiment with the entire satellite and payload weighing just 60 kg. This Near-Earth Surveillance System would track satellites in GEO orbit, as MSX does today. However, it would also be able to search the critical region near the sun for NEOs that would be missed by conventional surveys.

The U.S. DoD is planning a constellation of somewhat larger satellites to perform our basic satellite-tracking mission. Today our ground-based radars and telescopes, and even MSX, only track objects that we already know about. These systems are not true outer-space search instruments as the LINEAR system is. However, the future military space surveillance system would be able to search the entire sky. As an almost "free" by-product, it could also perform the NEO search mission. Larger aperture ground-based systems could then be used to follow up to get accurate orbits for the NEOs discovered by the space-based search satellites. Again, I believe there is considerable synergy between national security requirements related to man-made satellites and global security requirements related to NEO impacts.

Regardless of how well we know NEO orbits and can predict their impacts, the fact remains that today, we have insufficient information to contemplate mitigating an impact. We do not know the internal structure of these objects. Indeed, we have reason to believe that many, if not most, are more in the nature of "rubble piles" than coherent objects. This structure suggests that any effort to "push" or divert a NEO might simply fragment it, which could potentially turn a single dangerous asteroid into hundreds of objects that could damage a much larger area.

What is needed are in situ measurements across the many classes of NEOs, including asteroids and comets. This is particularly important in the case of small (100 meter) class objects of the type we would most likely be called upon to divert. Until recently, missions to gather these data would have taken up to a decade to develop and launch and cost hundreds of millions of dollars. However, the situation looks much better with the emergence of so-called "microsatellites," which weigh between 50-200 kg and can be launched as almost "free" auxiliary payloads on large commercial and other flights to GEO orbit. These missions can be prepared in one to two years for about $5-10M, and launched for a few million dollars as an auxiliary payload. I believe such auxiliary accommodation is a standard feature on the European Ariane launches, and could be considered here in the United States on our new Evolved Expendable Launch Vehicles.

With a capable microsatellite with several kilometers per second "delta-V" (maneuver capacity) launched into a GEO transfer orbit (the standard initial launch orbit for placing systems into GEO), the satellite could easily reach some NEOs and perform in situ research. This could include sample return, direct impact to determine the internal structure and the potential to move a small object. Indeed, NASA is planning several small satellite missions. The key point here, however, is that with missions costing $10M each, we can sample many types of NEOs in the next decade or so to gain a full understanding of the type of objects we face.

There is an interesting concept to consider. If we can find the right small object in the right orbit, we might be able to nudge it into an orbit "captured" by the earth. This would make a NEO a second natural satellite of earth. Indeed, there is at least one NEO that is close to being trapped by the Earth now, 2002 AA_{29}. If such an object were more permanently in earth orbit, it could be more closely studied and might form the basis for long-term commercial exploitation of space. Moreover, a very interesting manned space flight mission after the Space Station could be to an asteroid; maybe even one we put into earth's gravity sphere.

One important aspect of NEO mitigation is often overlooked. Most experts prefer to focus on the glamorous "mitigation" technologies–diverting or destroying objects. In fact, as the U.S. military knows well the harder part is what we call "command and control." Who will determine if a threat exists? Who will decide on the course of action? Who will direct the mission and determine when mission changes are to be made? Who will determine if the mission was successful? There are many more questions.

The U.S. military has long struggled with these command and control issues that now confront the NEO community. Earlier, I noted a concept of operations for the first step in NEO mitigation–a Natural Impact Warning Clearinghouse. I believe this command and control operation could catalog and provide credible warning information on future NEO impact problems, as well as rapidly provide information on the nature of an impact.

INTERNATIONAL ISSUES

Many have suggested any NEO impact mitigation should be an international operation. In my opinion, the United States should proceed carefully in this area. International space programs, such as the International Space Station, fill many functions. A NEO mitigation program would have only one objective. In my view, a single responsible nation would have the best chance of a successful NEO mitigation mission. The responsible nation would not need to worry about giving up national security sensitive information and technology as it would build and control the entire mission itself. As I have pointed out, the means to identify threats and mitigate them overlap with other national security objectives.

It does, however, make sense that the data gathered from surveys and in situ measurements be shared among all. This would maximize the possibility the nation best-positioned to perform a mitigation mission would come forward. One of the first tasks of the Natural Impact Warning Clearinghouse noted above could be to collect and provide a distribution point for such data.

ROLES OF THE U.S. MILITARY AND NASA

Currently, NASA has been assigned the task of addressing some NEO issues. The U.S. DoD has been asked to assist this effort. However, the U.S. DoD has not been assigned tasks, nor has any item relating to NEOs been included in military operational requirements. I believe one option would be for the U.S. DoD to assume the role of collecting available data and assessing what, if any, threat might exist from possible NEO collisions of all sizes. This does not mean other groups, in particular the international scientific community, should not continue their independent efforts. However, the U.S. DoD is likely, for the foreseeable future, to have most of the required sensors to do this job. Moreover, in my view, the U.S. DoD has the discipline and continuity to ensure consistent, long-term focus for this important job. As a consequence of this function, the U.S. DoD might collect a large quantity of important scientific data. To the degree that the vast bulk of this has no military security implications, it could be released to the international scientific community.

In addition, I believe NASA should continue the scientific task of assessing the nature of NEOs. Performing the necessary scientific studies, including missions to NEOs to gather data, is among NASA's responsibilities. Like the 1994 U.S. DoD/NASA Clementine probe, these missions could serve as important technological demonstrations for the U.S. DoD, and might be conducted jointly with NASA.

Should a threatening NEO be discovered, it is my opinion the U.S. DoD could offer much toward mitigating the threat. Of course, with a funded and focused surveillance program for cataloging and scientific study as outlined above, we should have ample time to debate this issue before it becomes critical.

SUMMARY

NEO mitigation is a topic whose time has come. I believe various aspects related to NEO impacts, including the possibility that an impact would be misidentified as a nuclear attack, are critical national and international security issues. The focus of NEO mitigation efforts–in finding and tracking them, and in exploring and moving some–should shift to smaller objects. The near-term threats are much more likely to come from these "small" objects (100 meters in diameter or so) and we might be able to divert such objects without recourse to nuclear devices.

After a suitable class of NEOs is found, microsatellite missions to explore and perhaps perform test divert operations could be considered. The technologies for low-cost NEO missions exist today.

The necessary command and control, sensor and space operations technologies and equipment are all "dual use" to the military. In my view, it stands to reason that strong military involvement should be considered in a national and international NEO program.